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Space Chemical Propulsion Test Facilities at NASA Lewis Research Center

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SPACE CHEMICAL PROPULSION TEST FACILITIES AT NASA LEWIS RESEARCH CENTER

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SUMMARY

The NASA Lewis Research Center, located in Cleveland, Ohio, has a number of space chemical propulsion test facilities which constitute a significant national space testing resource. The purpose of this paper is to make more users aware of these test facilities and to encourage their use through cooperative agreements between the government, industry, and universities. Research which is of interest to the government is especially encouraged and often can be done in a cooperative manner that best uses the resources of all parties.

This paper presents an overview of the Lewis test facilities. These facilities are clustered into three test areas: the Rocket Engine Test Facilities (RETF), the Rocket Laboratory (RL), and the Cryogenic Components Laboratory (CCL).

ROCKET ENGINE TEST FACILITIES (RETF)

The Rocket Engine Test Facility is a complex which contains the following test stands: (1) Sea-Level Rocket Engine Test Stand (A-stand), (2) Altitude Rocket Engine Test Stand (B-stand), and (3) Turbopump Test Stand (C-stand). Research programs are directed toward component testing of specific propulsion needs envisioned for future NASA missions. Programs include advanced thrust chamber heat transfer and cooling techniques, chamber life cycle testing, nozzle boundary layer predictions, combustion stability, and engine performance. To simplify the propellant feed complexities, the propellants are pressure fed to the engine.

An aerial photograph of the RETF is shown in figure 1. The complex comprises six buildings and extensive on-site support services. One building houses the two rocket engine test stands and shop area. A second building houses the turbopump test stand. Small outlying buildings house helium compressors, a liquid hydrogen pump and vaporizer, and liquid nitrogen pumps and vaporizers. A control building from which all operations are handled is located approximately 1250 ft from the test site.

The RETF contains pressurized propellant run tanks, propellant flow line systems, and a rocket exhaust gas treatment combination scrubber and silencing muffler. Located adjacent to the test cell area are 25 large-volume, high-pressure gas storage bottles, ranging in pressures from 4000 to 6000 psi. The support systems include permanent on-site bulk storage dewars for cryogenic liquid hydrogen, liquid oxygen, and liquid nitrogen, and a large water reservoir. The pressure and volume specifications of the pressure vessels, storage dewars, and water reservoir at RETF are shown in table I.

RETF has the flexibility for testing with cryogenic and Earth-storable propellants at high and low pressures. Liquid and gaseous hydrogen and oxygen, as well as liquid hydrocarbon, nitrogen tetroxide, and hydrazine propellants, have all been successfully tested at RETF. The following rocket test firings are performed: short duration (0.3 sec), multiple pulses (3.0-sec duration), and single continuous long runs of up to 100-sec duration.

Sea-Level Rocket Engine Test Stand (A-Stand)

Test stand A is designed for sea-level testing of vertically mounted rocket engines discharging into an exhaust gas scrubber and muffler. The test stand can handle a wide variety of propellant combinations and can support propellant run tank pressure levels to 5000 psig and thrust levels to 50 000 lb. Figure 2 shows A-stand with a mounted engine.

Altitude Rocket Engine Test Stand (B-Stand)

Test stand B is designed for altitude testing of horizontally mounted rocket engines exhausting into a diffuser, a cooler, and a two-stage ejector system. The test stand test-fires hydrogen-oxygen engines with thrust levels to 4000 lb at simulated altitudes to 180 000 ft. Figure 3 shows B-stand with a mounted engine.

Turbopump Test Stand (C-Stand)

Test stand C is designed for testing of cryogenic rocket engine turbopumps and turbopump components. Liquid hydrogen, liquid oxygen, and liquid nitrogen turbopumps and turbopump components can be driven with an assortment of high-pressure gases at ambient temperature. C-stand is shown in figure 4.

The operations at all three test stands are remotely controlled. Figure 5 shows an aerial photograph of the RETF control building. Programmable flow controllers and sequence timers provide automatic propellant flow control, remote sequence timing, and automatic permissive and cut-off control. Facility safety monitoring is also provided.

Data are recorded through a 200-channel, high-speed digitizer/multiplexer data acquisition system and fed through a direct digital data link to the Lewis Research Center central data system. The data are processed and then returned to the control room via hardcopy terminals and CRT's, thus providing on-line data reduction capabilities.

High-frequency-response analog data systems provide quick-look test data through oscillograph recorders. Low-frequency-response analog data are displayed on panel meters in the control room.

ROCKET LABORATORY (RL)

The Rocket Laboratory comprises 10 independent test facilities which perform basic research aimed at developing technologies for current and future space initiatives. Figure 6 shows an aerial photograph of the complex. The following facilities will be described here: (1) Low Thrust Propulsion Facility (Cell 11), (2) Low Thrust Rocket Facility (Cell 21), (3) High Heat Flux Thermal Shock Facility (Cell 22), and (4) Rocket Combustion Diagnostics Laboratory (Cell 32).

Low Thrust Propulsion Facility (Cell 11)

Hydrogen-oxygen thrusters are tested for performance and life in the Low Thrust Propulsion Facility (Cell 11), which is designed to test-fire rocket engines at altitude conditions and thrust levels to 50 lb.

This facility is capable of long-duration test firings at simulated altitudes to 120 000 ft. Cell 11 is shown in figure 7.

The propellants are supplied from gaseous hydrogen and gaseous oxygen tube trailers of 70 000 and 50 000 SCF capacity, respectively. The maximum flow rate of the gaseous hydrogen is 0.022 pps at 1200 psi, and the maximum flow rate of the gaseous oxygen is 0.08 pps at 1000 psi. Air-driven ejectors are used to evacuate the vacuum tank. Test operations are remotely controlled with a programmable logic controller (PLC). The data system can record up to 2500 samples of data per second. A laser is used to perform nonintrusive studies of the rocket engine exhaust plumes.

Low Thrust Rocket Facility (Cell 21)

At the Low Thrust Rocket Facility (Cell 21), research activities include multi-compartment ignition techniques and in situ propellant and metallized propellant performance testing. The facility can be operated at either atmospheric or altitude exhaust conditions at thrust levels up to 100 lb. Cell 21 is shown in figure 8.

Gaseous hydrogen, gaseous methane, gaseous carbon monoxide, RP–1, liquid propane, and metallized propellants can be supplied to the facility. Gaseous oxygen is used as the oxidizer for all testing. A 50 000 SCF gaseous oxygen tube trailer supplies oxygen at a maximum flow rate of 0.10 pps at 1500 psig. Gaseous methane and carbon monoxide are supplied into a manifold system from K-bottle cylinders. The K-bottle capacity is 1200 SCF at pressures up to 1600 psig. Liquid fuel is supplied from eight 1-gal tanks with working pressures to 1500 psig. Metallized propellant fuels are fed to the cell at pressures to 1250 psig. Air-driven ejectors provide altitude capabilities.

A programmable logic controller is used to sequence valve operations. Data capabilities include a high-speed data acquisition system (100 channels) with an overall digitizing rate of 50 000 samples per second and a low-speed data acquisition system (111 channels) with a digitizing rate of approximately 80 samples per second.

High Heat Flux Thermal Shock Facility (Cell 22)

At the High Heat Flux Thermal Shock Facility (Cell 22), research is conducted on ceramic composites, transpiration-cooled seals, thin film thermocouples, and leading edge erosion and oxidation. A 1000-lb-thrust gaseous hydrogen/gaseous oxygen rocket engine is used as a workhorse for testing specimens mounted in the rocket engine exhaust plume. The samples are subjected to temperatures to 5500 °F. The data acquisition systems described for Cell 21 are shared with Cell 22. A programmable logic controller is used to control the test operations. The facility is shown in figure 9.

Rocket Combustion Diagnostics Laboratory (Cell 32)

The Rocket Combustion Diagnostics Laboratory (Cell 32) is shown in figure 10. The cell is currently under construction and will be completed by mid-1993. The facility will initially be used to verify combustion stability models.

The cell is designed for test-firing gaseous hydrogen/liquid oxygen or gaseous hydrogen/gaseous oxygen rocket engines at thrust levels to 2000 lb for short-duration performance characterizations. The propellants systems are supplied from gaseous hydrogen and gaseous oxygen tube trailers of 70 000 and 50 000 SCF capacity, respectively. Liquid oxygen will be supplied from a 50-gal tank with a working pressure of 1800 psig.

Data capabilities include a high-speed data acquisition system (150 channels) with an overall digitizing rate of 600 000 samples per second and a low-speed data acquisition system (111 channels) with a record rate of approximately 80 samples per second. A programmable logic controller is used to control the test operations.

Several ports for optical access are located in the main blast wall which separates the test cell from the laser room. This arrangement will allow the use of laser diagnostic equipment to study complex flow phenomena. A phase Doppler droplet analyzer (PDDA) will measure injector spray droplet size and study velocity characteristics. A laser Doppler velocimeter (LDV) will measure the velocity of droplets and particles in the flow stream. A copper vapor laser flow visualization system will provide qualitative and quantitative flow data. A laser spectroscopy system is planned for the future.

CRYOGENIC COMPONENTS LABORATORY (CCL)

The Cryogenic Components Laboratory is a complex of five small test facilities surrounding a centrally located control building. The complex (fig. 11) is designed for hazardous test operations, with each of the buildings separated by earthen blast mounds. Gaseous nitrogen and gaseous helium at working pressures of 2400 psi, along with air at 120 psi, are fed to each of the test cells through centralized manifold systems. Gaseous nitrogen is supplied from 250 000 SCF bottles at flow rates to 2000 SCFM. Gaseous helium is supplied from a 70 000 SCF tube trailer at flow rates to 2000 SCFM. Low-speed data acquisition systems, with sampling rates of 1 sample per second per channel, support each test cell.

In cell 1, a 225-ft^2 building, research programs are conducted on the performance and life testing of liquid oxygen and liquid nitrogen bearings and seals. The building has a dedicated 3000-gal run tank with a working pressure of 250 psi. A cryogenic pump, rated at 75 gal/min and 1500 psig, supplies the fluid to the testers.

Cell 2 is also 225 ft^2. Research programs include the performance of small liquid hydrogen pumps and health monitoring code predictions for bearings and seals. The facility has a dedicated 1300-gal liquid hydrogen vacuum-jacketed run tank rated for 1400 psig. Gaseous hydrogen, for driving the turbine and pressurizing the run tank, is supplied from two 70 000 SCF tube trailers.

Cell 4 is being reconfigured for fundamental experiments on rocket turbopumps. The building will be enlarged to 1500 ft^2 and will house a closed-loop water tunnel. The tunnel will be used to test and evaluate the sensitivity of pump design parameters with stall characteristics. The water pump will be driven with a 600-hp electric motor and gear box drive system.

Cell 5 is a 400-ft^2 building which is configured for handling high-pressure liquid and gaseous hydrogen fundamental experiments. The current program is the evaluation of catalysts for converting from para-to-ortho hydrogen. The facility has a dedicated 560-gal liquid hydrogen vacuum-jacketed run tank with a working pressure of 1400 psig. Gaseous hydrogen is supplied to the facility from a 70 000 SCF tube trailer.

Cell 7 is a 225-ft^2 building which is configured to handle small liquid hydrogen and liquid nitrogen fundamental experiments. Research has been focused on nonventing cryogen transfer experiments. The test cell has no permanent cryogenic supply systems. The experiments depend on roadable dewars as required.

CONCLUDING REMARKS

NASA encourages cooperative activities involving industry, universities, and other government agencies in areas of mutual interest. The facilities described provide a broad capability that can be applied to research and development in many technical areas. Persons interested in pursuing joint activities or using these facilities should contact the chief of the Space Propulsion Technology Division, Dr. Larry A. Diehl, at 216–977–7505.

TABLE I.—PRESSURE AND VOLUME SPECIFICATIONS FOR PRESSURE VESSELS, STORAGE DEWARS, AND WATER RESERVOIR AT THE ROCKET ENGINE TEST FACILITIES

	Volume	Maximum working pressure, psig
Liquid hydrogen run tanks	1300 gal 1000 gal	1500 5000
Liquid oxygen run tanks	400 gal 400 gal	1500 5000
Water tanks	1300 gal 600 gal	1500 5000
Hydrocarbon run tank	600 gal	5000
Gaseous hydrogen high-pressure bottles	390 000 SCF	4000
Gaseous oxygen tuber	70 000 SCF	2400
Gaseous helium high-pressure bottles	160 000 SCF	4000
Gaseous helium high-pressure bottle	100 000 SCF	6000
General-usage high-pressure bottles for gaseous hydrogen, helium, and nitrogen	290 000 SCF	6000
Water reservoir	500 000 gal	-----
Liquid hydrogen storage dewar	19 000 gal	-----
Liquid nitrogen storage dewar	28 000 gal	-----

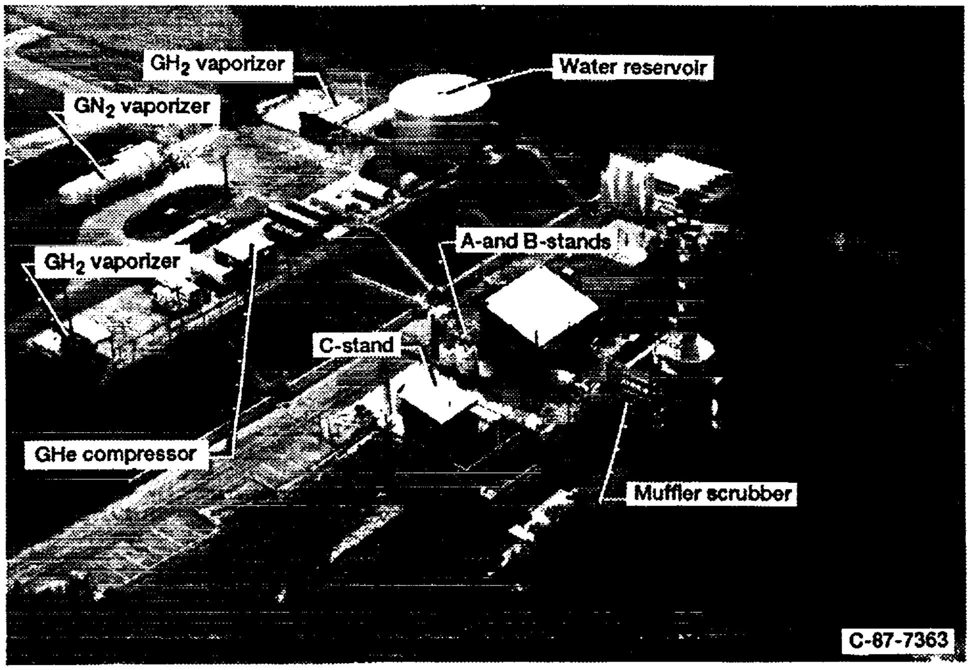

Figure 1.—Rocket Engine Test Facilities (RETF) complex.

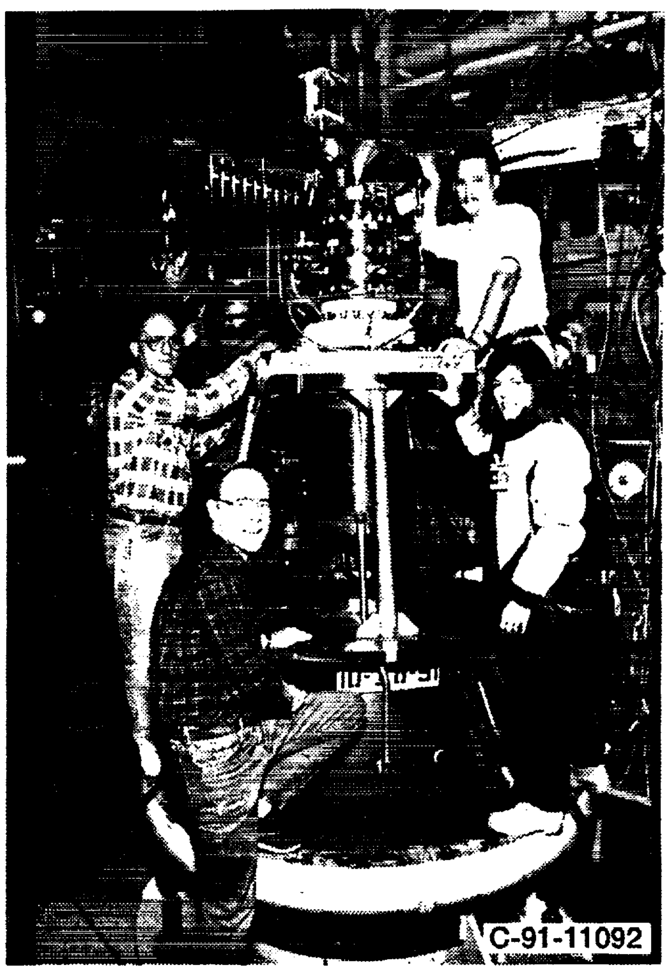

Figure 2.—Engine mounted on A-stand.

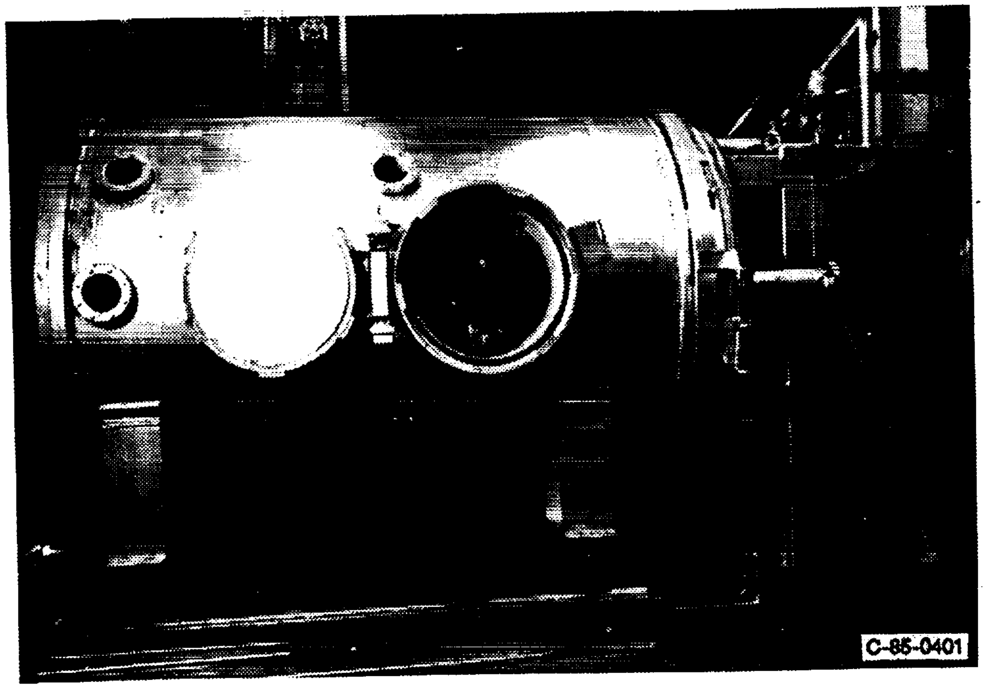

Figure 3.—Engine mounted on B-stand.

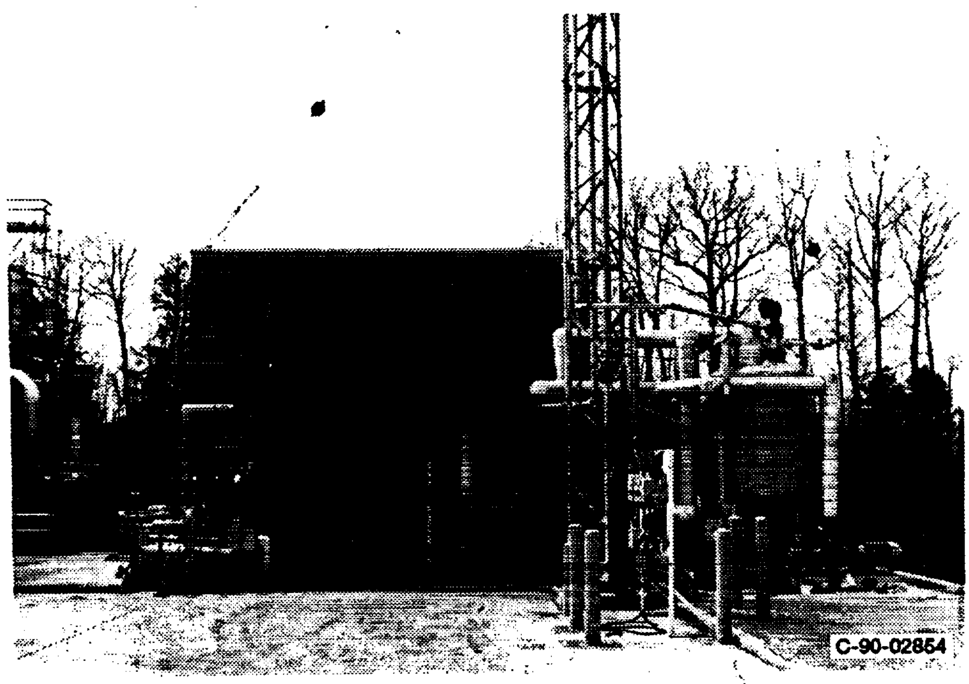

Figure 4.—C-stand.

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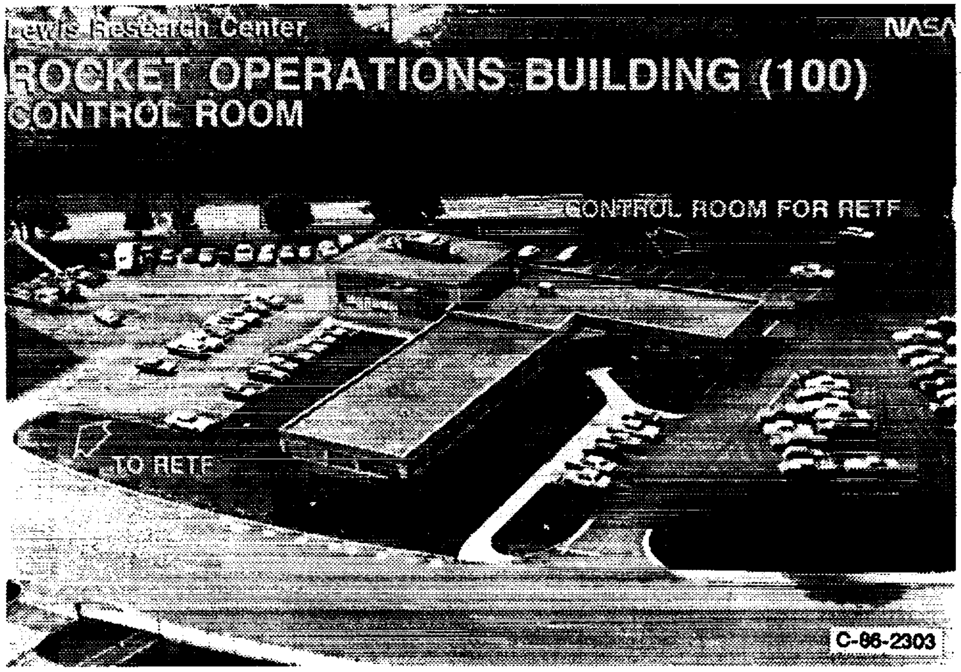

Figure 5.—Control building.

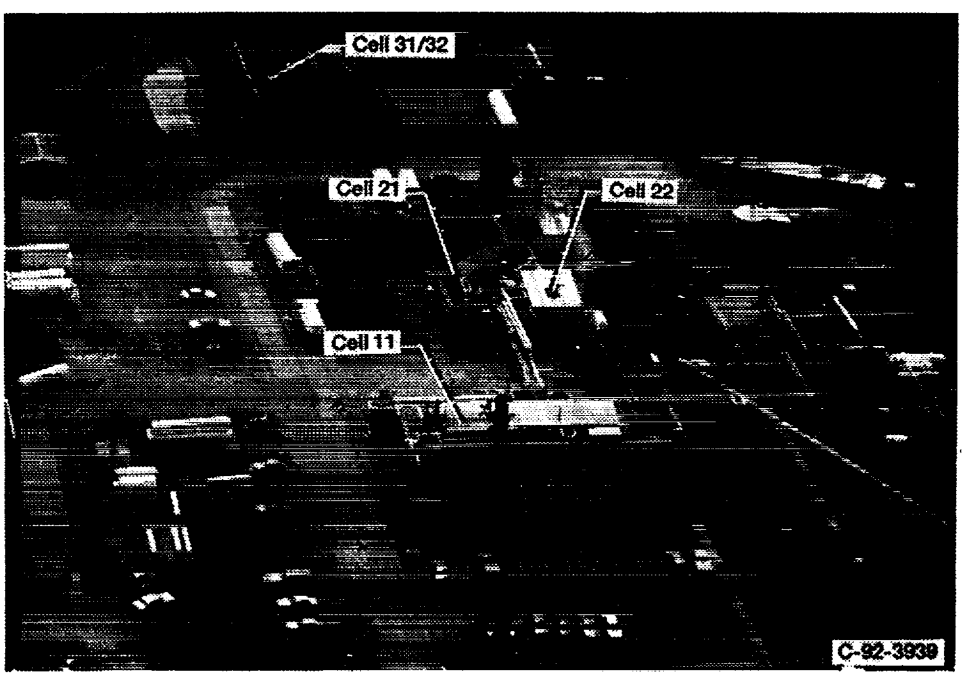

Figure 6.—Rocket Laboratory complex.

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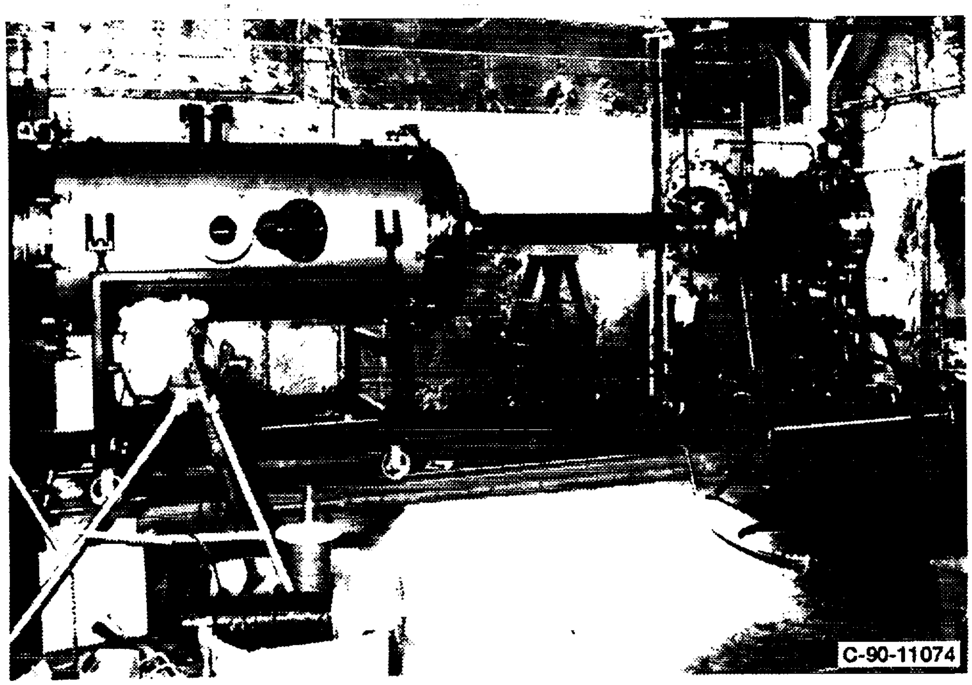

Figure 7.—Low Thrust Propulsion Facility (Cell 11).

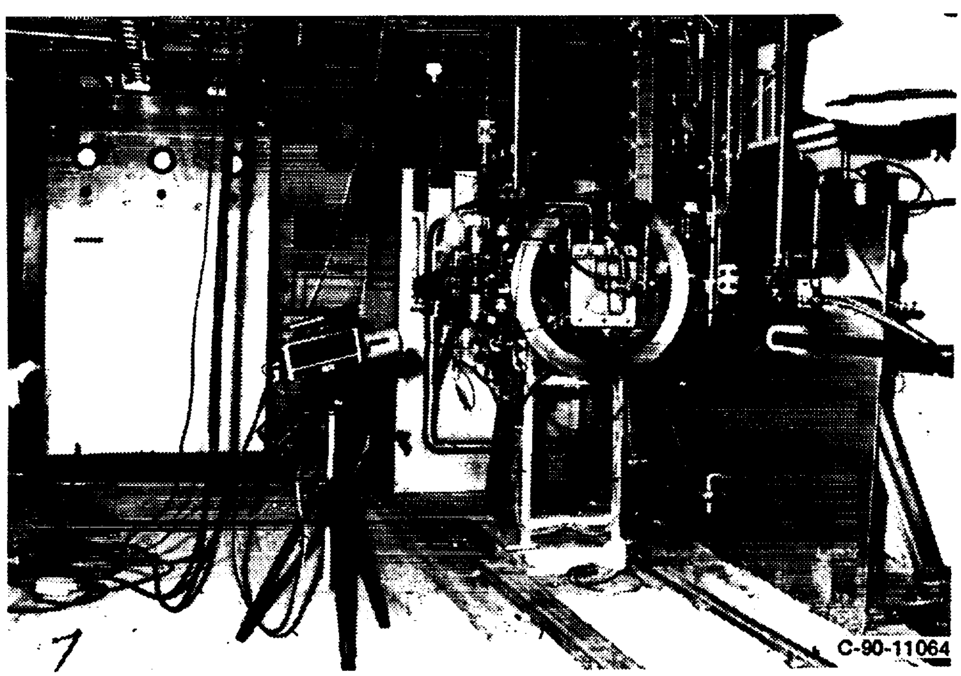

Figure 8.—Low Thrust Rocket Facility (Cell 21).

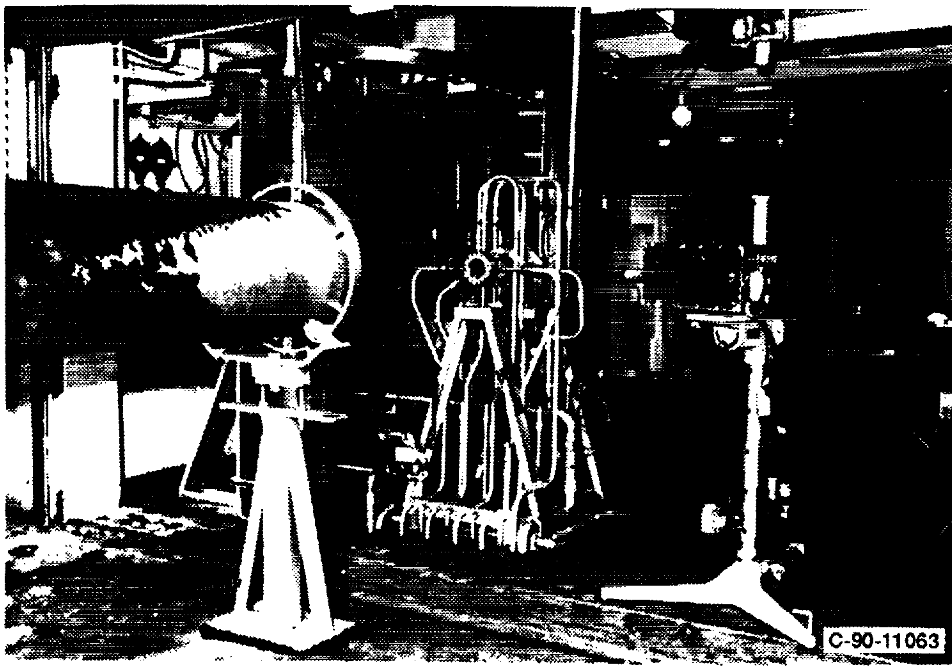

Figure 9.—High Heat Flux Thermal Shock Facility (Cell 22).

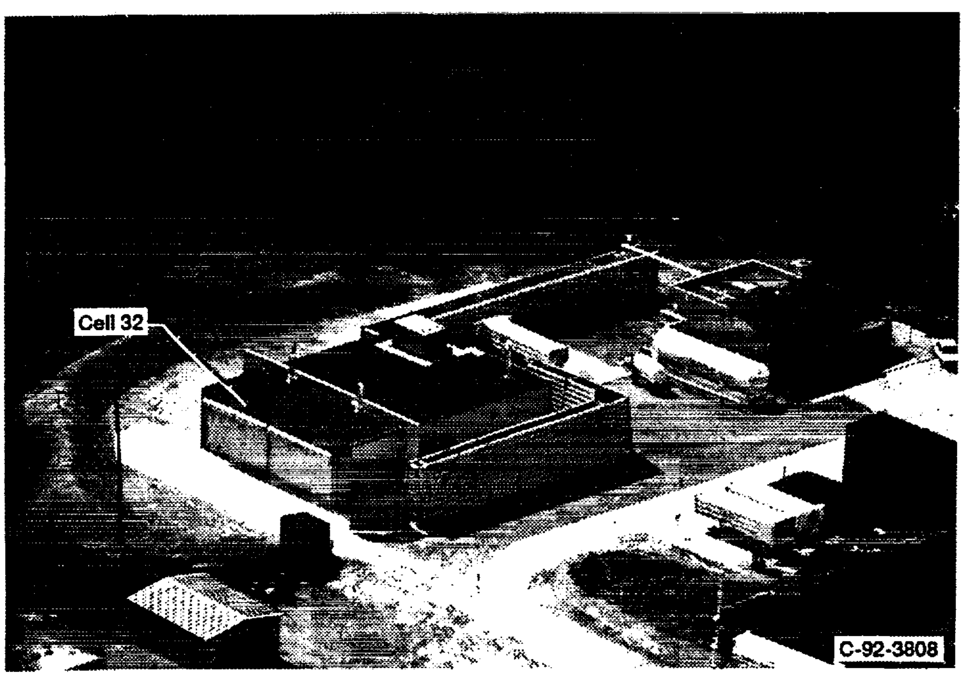

Figure 10.—Rocket Combustion Diagnostics Laboratory (Cell 32).

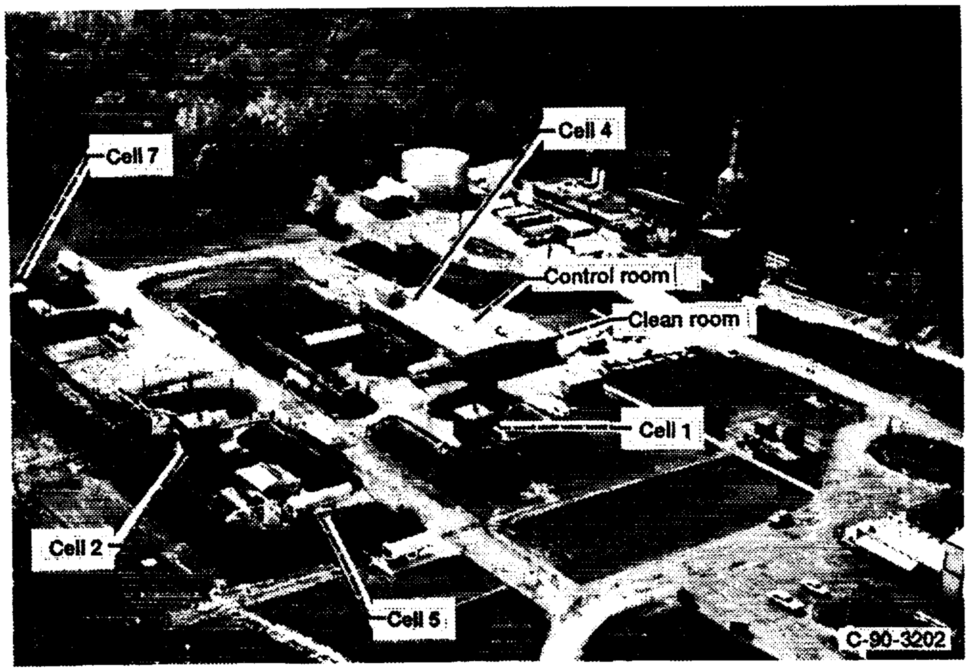

Figure 11.—Cryogenic Components Laboratory complex.

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13. ABSTRACT ***(Maximum 200 words)***

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